A SYSTEM AND A METHOD OF CONTROLLING THE TRIGGERING OF A TRIAC

This application claims the priority of Brazilian patent case N°. PI0305983-9 filed on December 30, 2003, the content thereof being hereby incorporated by reference.

The present invention relates to a system of controlling and triggering a TRIAC as well as to a method of controlling the triggering of a TRIAC, by actuating a load with any power factor from a single short-duration pulse at the TRIAC gate.

Description of the Prior Art

As known from the prior art, TRIAC's are switches used mainly for controlling the level of voltage on a load.

In order to actuate a TIRAC, it is necessary to supply or drain a current pulse from the gate with respect to the main terminal 1 for an interval of time that enables the current circulating through the main terminals of the TRIAC to reach a minimum value, known as latch current. Once the current has reached this value, the pulse at the gate may be released, and the current will be naturally conducted until the instant at which it reaches a value lower than the maintenance current, known as hold current. If there is current drained or supplied to the gate at the instant when the current reaches the hold value, the TRIAC again goes into conduction and will remain in this condition if the gate signal is maintained again until the current between the main terminals reaches the latch current. The cycle may then be indefinitely repeated, to keep the TRIAC in conduction, if the current circulating through the TRIAC is monitored and the pulses at the gate are generated at the correct instants. Besides enabling the continuous conduction of the TRIAC, the monitoring of the current through the component makes possible the adequate triggering when the adjustment of the triggering angle to control the effective voltage or current in the load is wished.

There are various ways of monitoring the current that circulates through the terminals of the TRIAC for controlling its triggering at the instant immediately preceding the passage of this current by zero. One of these

ways consists in monitoring the current by mans of an element in series with the TRIAC, for example, a resistor and, in as a function of the voltage read on this resistor, determining whether the current is coming close to zero value. Another way of monitoring the zero of the current consists in detecting the voltage between the main terminals of the TRIAC, but in this case the detection of voltage between the terminals indicates that the TRIAC is already in the open state and, even if it is immediately triggered, the component has already discontinued the current. The most effective method for monitoring current by means of the TRIAC consists in measuring the voltage at the gate with respect to the main terminal 1, which reflects the current that circulates through the main terminals. This idea is described in the North American patent documents US 5,629,571 and US 5,734,289. In Roudeskl (US 5,629,571), two comparators are used, in addition to various other elements for controlling the circuit, so that the circuit could not be implemented directly by using low-cost microcontrollers. Further, according to the teachings of this reference, the monitoring of the voltage at the gate of the TRIAC is foreseen. This document, however, does not disclose the adjustable control of this magnitude as a function of the current circulating in the load, which results in an application with a limited range of current in the load.

In Khudoshin (US 5,734,289), two comparators are also used, and the implementation may be made by using a microcontroller. However, just as in the preceding case, the circuit does not allow one to monitor a wide range of current values by means of the TRIAC, which entails failure at the command of the TRIAC gate or long-duration pulse at the gate.

The functioning principle of the circuits consists in comparing the voltage measured at the TRIAC gate with respect to the main terminal 1, which directly reflects the current conducted by the TRIAC with prefixed voltage values, which may be called voltage +limit and -limit values. If the voltage measured at the gate is between the +limit and -limit values, there is generation of a signal to the TRIAC gate. In order to compare the voltage measured at the gate with two different values, the circuits make use of two analog comparators. Figure 3 represents the voltage curve at the gate

equivalent to the instant of passage of two currents called I_1 and I_2 by zero, as well as the positive value of the comparison voltage, called +limit. The same curve is symmetrically repeated during the rise of the current, passing, in this case, by the -limit.

When the voltage at the TRIAC reaches, during the drop of the current, the +limit value, which is represented by the instant t_1 when the voltage of the gate is equivalent to a current I_1 and at the instant t_2 when the voltage of the gate is equivalent to another current I_2, the circuit generates one of more pulses at the TRIAC gate. As can be seen in figure 3, the higher the value of the current, the shorter the time between the detection by the comparator and the passage by zero.

The drawback of the different detection times lies in the fact that the control units need a minimum time for analysis of the measured signal and actuation of the power step, to actuate the TRIAC gate and, if the time is very short, the processing unit will not perform the tasks of actuating at the correct instant. On the other hand, if the time is too long, the control unit has to generate a signal with a proportionally great broadness for actuating the TRIAC.

Thus, in order to solve this problem, it would be possible to fix higher and lower values for +limit and -limit, according to the current expected for the TRIAC, but any variation of this current out of the pre-established limits will entail the above-described problems. Therefore, it can be noticed that the circuits proposed in patents US 5,629,571 and US 5,734,289 have the drawback of permitting operation only with restricted and previously defined values of current.

Objective and Brief Description of the Invention

The present invention has the objective of providing a circuit for controlling and triggering a TRIAC, by using only one short-duration pulse during the passage of the current circulating through the main terminals of this TRIAC by zero. The following are characteristics of the circuit:

- the possibility of implementation by using a simple and low-cost control unit;

- the utilization of only one analog comparator for implementation of the circuit;

- the utilization of a very simple digital-to-analog D/A converter;

- the adequate control of the TRIAC for any value of load current and power factor of the load.

Thus, in order to achieve the objectives of the present invention, the system should detect, through the control unit, the level transition from the comparator output to actuation of the TRIAC. The comparator receives voltage signals from the TRIAC gate and voltage from a D/A converter, the latter being controlled by the control unit and the level transition from the comparator output occurs during the transitions of the current induced by the TRIAC from the negative state to the positive state and vice-versa (which may also be measured from the voltage at the gate), a moment when a pulse should be generated at gate G of the TRIAC with a duration that enables the current to reach the latch value.

In this way, the control unit will command the D/A converter to commute between a positive voltage +limit to a negative -limit and vice-versa at every transition received by the comparator CP_1. A single comparator may be used instead of the pair of comparators used in the prior art and thus generate two levels of voltage +limit and -limit.

Additionally, according to the teachings of the present invention, in order to solve the problem described before relating to different voltage values, the +limit and -limit values are varied proportionally to the values of the current circulating in the load, so that the time between the detection of the limits and the passage of the current by zero can occur in a fixed time, adequate for actuating the TRIAC correctly.

Such an adjustment of level of the +limit and -limit may be made from the calculation establishing:

$$\pm Limit = k \times I_C$$

wherein k is a proportionality constant that should be previously determined

and adjusted as a function of the characteristics of the circuit; and *Ic* is the current circulating in the load.

Another way of making the adjustment of the +limit and –limit value is by means of a table of pre-established values stored in the control central 44 of the control unit 4, where a value of the current measured in the load is put and the +limit and –limit values are established that should be adopted for the situation of the moment.

The objectives of the present invention are achieved by means of a TRIAC controlling and triggering system, the TRIAC comprising a gate, the TRIAC being connected to a load, the gate being electrically connected to a power unit that actuates the TRIAC for selectively applying a network voltage to the load and enabling the circulation of an electric current in the load, the system comprising a gate-voltage detection unit, a power unit and a control unit, the voltage detection unit being electrically connected to the control unit, the control unit establishing a gate-voltage limit value (+limit, -limit), and generating a pulse at the TRIAC gate to maintain it in conduction, the pulse at the gate being generated from a comparison between the voltage limit value (+limit, -limit) established by the control unit and a voltage measured at the gate from the gate-voltage detection unit. The control unit further measures the electric current and adjusting the voltage limit value (+limit, -limit) in a way proportional to the measured current value.

Further, according to the teachings of the present invention, the objectives aimed are achieved by means of a method of controlling the triggering of a TRIAC, the TRIAC comprising a gate and being electrically connected to a network voltage, the TRIAC being selectively actuated from the pulse at the gate to apply the network voltage to a load, enabling the circulation of a current, a comparator being associated to the TRIAC gate, the method comprising steps of applying a pulse at the gate when the voltage limit value (+limit, -limit) at the gate is detected, the pulse being generated from a transition at the comparator, the comparator comparing the voltage limit value (+limit, -limit) at the gate and a voltage measured at the gate; commuting the input of the comparator between a positive voltage limit

(+limit) to a negative limit (-limit) and vice-versa at every transition received by the comparator. The method further comprises steps of, before applying the pulse at the gate, measuring the current that circulates in the load, and adjusting the level of the voltage limit value at the gate (+limit, -limit) in a way proportional to the level of the current.

Further, according to the teachings of the present invention, the above objectives are achieved by means of a method of controlling the triggering of a TRIAC, the TRIAC comprising a gate and being electrically connected to a network voltage, the TRIAC being selectively actuated from a pulse at the gate to apply the network voltage to a load, enabling the circulation of a current, the method comprising steps of: applying a pulse at the gate when the current value is a minimum value, the pulse at the gate being generated in a previously established measurement time, the measurement time occurring before the passage of the current by zero, measuring the current that circulates in the load, and adjusting the level of the voltage limit value (+limit, -limit) of the gate in a way proportional to the level of the current.

Brief Description of the Drawings

The present invention will now be described in greater details with reference to the figures described hereinafter.

- Figure 1 is an electric diagram of the system according to the present invention;

- Figure 2 is a diagram of the wave forms relating to the operation of the system;

- Figure 3 is a diagram of the wave forms illustrating gate voltage per time, as a function of the varied currents, in the systems known from the prior art; and

- Figure 4 is a diagram of the wave forms illustrating the gate voltage per time, as a function of the varied currents, applying the teachings of the present invention, with an adjustment of variable limit references for actuating the gate.

Detailed Description of the Figures

According to figure 1, it can be seen that the TRIAC controlling

and triggering system of the present invention essentially comprises a gate-G voltage detection unit 1, a detection unit for detecting the passage of the voltage from the feed network 2 by zero, a current sensor 5, a power unit 3 and a control unit 4. The current sensor 5 may be constituted by a low-resistance resistor in series with the load, or still a Hall-effect sensor.

The voltage detection unit 1 comprises a resistive divider formed by the resistors R_1 and R_2, which are associated to the gate G of the TRIAC TR at the input of the resistor R_1 and associated to an input of the comparator CP_1, which is associated between the resistors R_1 and R_2. A digital-to-analog (D/A) converter is interconnected to the other input of the comparator CP_1 and to a control central 44. The control central 44 may be implemented by means of discrete components, but preferably a microprocessor or a microcontroller is used and a control central 44, which has already the comparator CP_1 inside it may be used.

The detection unit for detection of the passage of the feed network 2 voltage by zero comprises protection diodes D_1, D_2, associated to a direct current voltage V_{DC} and through which the network voltage V_{AC} is fed passing through a resistor R_4. The detection unit for detecting the passage of the feed network 2 voltage by zero also receives a command to turn on the system, both being associated to the control central 44.

The power unit 3 comprises a power switch 33, which is interconnected between the control central 4 and the gate G of the TRIAC TR through a resistor R_3, while the control unit 4 comprises a control central 44 and the D/A converter. Optionally, the power switch 33 may be inside the control central 44. The power unit 3 may comprise semiconductors capable of supplying and/or draining current sufficient to actuate the TRIAC.

The control unit 4 receives signals of the passage of the feed network voltage V_{AC} by zero, through the connection of a digital input of the control central 44 by means of the resistor R_4 and of the protection diodes D_1, D_2, and also receives signals from the comparator associated to the gate G of the TRIAC TR, and a command signal to turn on the circuit. As an output, the control central 44 may command the power unit 3 through the power

switch 33 to actuate the gate G of the TRIAC TR and may further define a voltage value at one of the inputs of the comparator CP_1, for instance, the non-inverting input, through the D/A converter. The D/A converter used may have low-resolution, since the input at the non-inverting port of the comparator CP_1 may be operated with some voltage levels (which will, for instance, adjust the voltage limit values), and a D/A converter may be used inside or outside the control central 44.

Operationally, the system, after receiving the torn-on command at the control central 44, waits for the passage of the feed network voltage VAC by zero, detected by the control central 44 through the resistor R_4. The detection is made during a transition of the network voltage V_{AC} from the negative state to the positive one, for instance, a moment when a pulse at the gate G of the TRIAC TR should be generated with such a duration that enables the current to reach the latch value. Simultaneously the control unit 44 determines that the output of the D/A converter should be equal to a (+limit)/2 value, if $R_1 = R_2$ and waits for the output of the comparator CP_1 to go to the high level. As already described, the +limit and –limit value is such that, when the voltage at the gate G reaches this value, the current i_C in the load will be higher than the hold current of the TRIAC. At the instant when the output of the comparator CP_1 goes to the high level, the control unit 4, through the power unit 3, generates a new pulse at the gate G of the TRIAC TR, since the current i_C approaches zero. The pulse generated should have a duration sufficient to guarantee that the current i_C will again reach the latch value. After the pulse, the control unit 4 determines, at the output of the D/A converter, a value equal to (-limit)/2 and awaits until the output of the comparator goes this time to the low level, generating a new pulse at the gate G of the TRIAC TR. The cycle then may be repeated as long as there is command to turn on the circuit. The control over the D/A converter is effected from a digital signal generated by the control central 44 and the latter, in turn, establishes an adjustment voltage value equal to the +limit and –limit voltage limits.

The adaptability of the system to a broad range of current values

by the TIRAC TR is guaranteed by reading the circulating current i_C, which allows the control central 44 to correct the –limit and +limit value as a function of this read current. This solution also enables the use of a single comparator CP_1, since two gate-G voltage limit values (+limit, -limit) are used.

From figure 4, it is possible to follow the result of the correction of the voltage applied to the comparator CP_1 through the D/A converter as a function of the current i_C, resulting in a fixed time or measurement time t_M between the detection of the gate voltage value (+limit, -limit), which is now variable, and the passage by zero, being sufficient for actuation of the control unit 44 and for permitting a narrow broadness of the pulse applied to the gate G of the TRIAC TR.

Thus, the greater the current i_C, detected by the current detector 5, the higher the magnitudes of the values of the positives and negatives limits of gate voltage (+limit and –limit) and, inversely, the lesser the current i_C, the lower these values, guaranteeing the generation of pulses with the exact broadness for triggering the TRIAC TR. In any situation, a pulse with a narrow broadness may be generated at the gate G, since this will be always be made from the measurement time t_M, which should be previously established to guarantee that the pulse generated at the gate G will have the desired effectiveness, and it should always occur before the passage of the level of the current i_C by zero.

In addition to the continuous triggering of the TRIAC TR, maintaining the network voltage V_{AC} entirely on the load, it is further possible for the voltage V_{AC} to be adjusted to a voltage value in the load from the delay in generating the pulses at the gate G of the TRIAC TR, independently of the power factor of this load, since it is the current circulating through the TRIAC TR that is being monitored.

Specifically with regard to the method for controlling the TRIAC TR, the steps of applying a pulse at the gate G when the voltage limit value (+limit, -limit) at the gate G is detected should be proceeded, the pulse being generated from a transition at the comparator CP_1, the comparator CP_1 comparing the voltage limit value (+limit, -limit) at the gate G and a voltage meas-

measured at the gate G, and commuting an input of the comparator CP_1 from a positive voltage limit (+limit) to a negative limit (-limit) and vice-versa at every transition received by the comparator CP_1.

Additionally, a step of adjusting the voltage limit values at the gate +limit, -limit is foreseen, which is carried out by applying the equation $\underline{\pm}Limit = k \times Ic$ from the control central 44, the step of measuring the current i_C being constantly carried out.

Another way of carrying out the step of adjusting the +limit and –limit value is by means of the table of pre-established values stored at the control central 44 of the control unit 4, where the value of the current measured in the load is entered and the +limit and –limit values are established that should be adopted for the situation of the moment.

A preferred embodiment having been described, one should understand that the scope of the present invention embraces other possible variations, being limited only by the contents of the accompanying claims, which embrace the possible equivalents.